Inclusive A_{LL} Measurements at STAR

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Abstract. One of the primary goals of the RHIC Spin program is to determine the gluon polarization distribution within the proton. At leading order, pp collisions involve a mixture of quark-quark, quark-gluon, and gluon-gluon scattering. In RHIC, the gluon-gluon and quark-gluon contributions dominate, making the accelerator an ideal tool to explore gluon polarization. The STAR experiment has measured the longitudinal double-spin asymmetry A_{LL} for inclusive production of jets and pions, and for charged pion production opposite a jet, at $\sqrt{s} = 200 GeV$. The results provide valuable new constraints on the gluon polarization in the proton when included in a next-to-leading-order global analysis. The current status of the STAR measurements and the plans for future measurements will be discussed.

1. Introduction

Collisions of polarized protons at the Relativistic Heavy Ion Collider (RHIC) offer a window into the spin composition of the proton through measurements of longitudinal double-spin asymmetries in a variety of final states [1]. Jet and pion production at STAR [2] is dominated by gg and qg scattering, providing sensitivity to the polarized gluon distribution $\Delta g(x, Q^2)$ over a restricted kinematic region of $0.03 < x < 0.3$.

One can write the longitudinal double-spin asymmetry A_{LL} in terms of experimental quantities as

$$A_{LL} = \frac{1}{P_1 P_2} \frac{N^{++} - R N^{+-}}{N^{++} + R N^{+-}}, \tag{1}$$

where $P_{1,2}$ are the polarizations of the colliding proton beams, N^{++} and N^{+-} are the identified particle yields when the proton helicities are aligned and anti-aligned, and R is the ratio of the beam luminosities in the two helicity configurations. The beam polarizations at RHIC are measured every few hours using a high-statistics Coulomb Nuclear Interference (CNI) polarimeter [3], and the analyzing power of the CNI polarimeter is normalized using a gas jet polarimeter [4]. The spin-dependent relative luminosities are measured at STAR using the Beam Beam Counters (BBCs), segmented scintillator annuli located up and downstream of the STAR interaction region that provide full azimuthal coverage. Coincident signals in the two BBCs define STAR's pp minimum-bias trigger condition; this approach samples 87% of the non-singly diffractive scattering cross section [5]. The BBCs can also be used to measure residual transverse beam polarization, which manifests as an azimuthal asymmetry in the scintillator tile counts [6]. The minimum-bias trigger condition is necessary but not sufficient to select events for the analyses reviewed here. Also required is an transverse energy deposit in one of the electromagnetic calorimeters which enhances STAR's sampling of hard scattering events.

(a) inclusive jet A_{LL} (b) recent Δg analysis
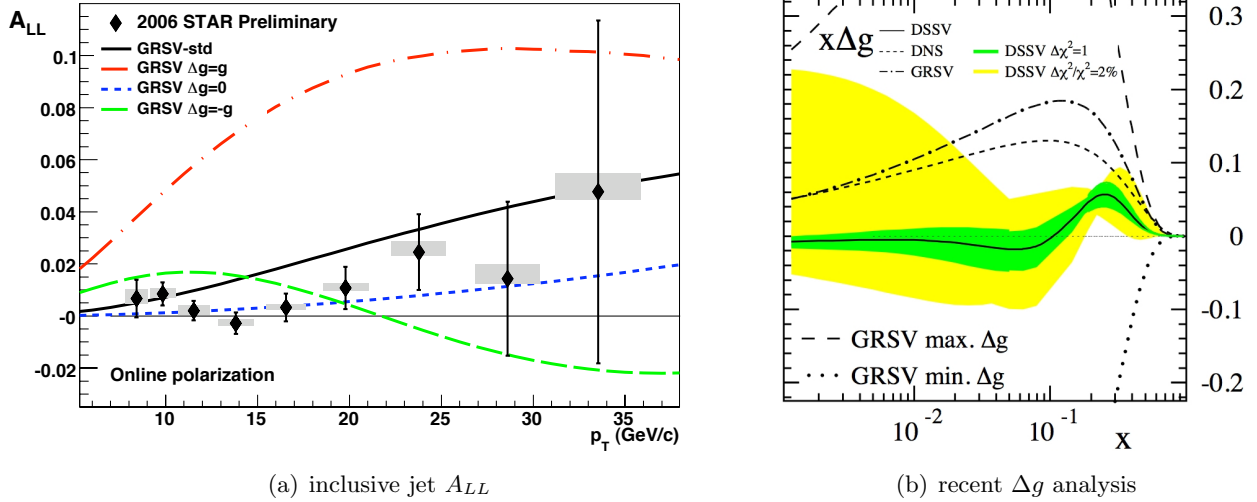
Figure 1. Full jet reconstruction capabilities enable the flagship inclusive A_{LL} measurement at STAR. The left panel shows the most precise measurement of inclusive jet A_{LL} to date, obtained using Run 6 data. The right panel shows a recent global analysis of the polarized gluon polarization, the first such analysis to incorporate measurements from RHIC.

2. Jets

Jets are reconstructed at STAR using a midpoint cone algorithm [7] that clusters charged track and electromagnetic energy deposits within a cone of radius $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$. Earlier measurements used a smaller 0.4 cone radius because the Barrel Electromagnetic Calorimeter (BEMC) was not yet fully commissioned. Charged track momenta are measured by the Time Projection Chamber (TPC). Neutral energy deposits are measured by the Barrel and Endcap EMCs. Events are selected using a Jet Patch (JP) trigger algorithm that looks for a transverse energy deposition in fixed $\Delta\eta \times \Delta\phi = 1.0 \times 1.0$ patches of the BEMC above some threshold. In the 2006 RHIC run, that threshold was primarily set at 8.3 GeV.

Figure 1(a) presents STAR's preliminary measurement of inclusive jet A_{LL} obtained by analyzing 4.7 pb^{-1} of data collected during the 2006 RHIC run [8]. The uncertainties on the data points are statistical; the gray bands plot asymmetric point-to-point systematic uncertainties. The data are compared to a variety of predictions for A_{LL} assuming various input distributions for the gluon polarization in the GRSV framework [9].

The inclusive jet data from STAR (as well as π^0 data from PHENIX) have been incorporated into a global analysis used to extract polarized parton distribution functions [10]. The right panel of Figure 1 shows the result of this analysis for $\Delta g(x)$; compared to previous global analyses, the uncertainties on the pdf shrink dramatically in the kinematic regime sampled by inclusive RHIC channels ($\sim 0.03 < x < \sim 0.3$).

3. Neutral Pions

Pions decaying via the two photon channel are reconstructed over a wide range in rapidity at STAR by a suite of electromagnetic calorimeters. The Barrel and Endcap EMCs are lead-scintillator sampling calorimeters that use shower maximum detectors situated a few radiation lengths into the detector to resolve decays where both photons are coincident on the same tower, thus extending the p_T reach of the measurements as high as 16 GeV/c. The Forward Pion Detector (FPD) is comprised of lead-glass cell matrices situated $\sim$750 cm from the interaction

(a) BEMC

(b) EEMC

(c) FPD
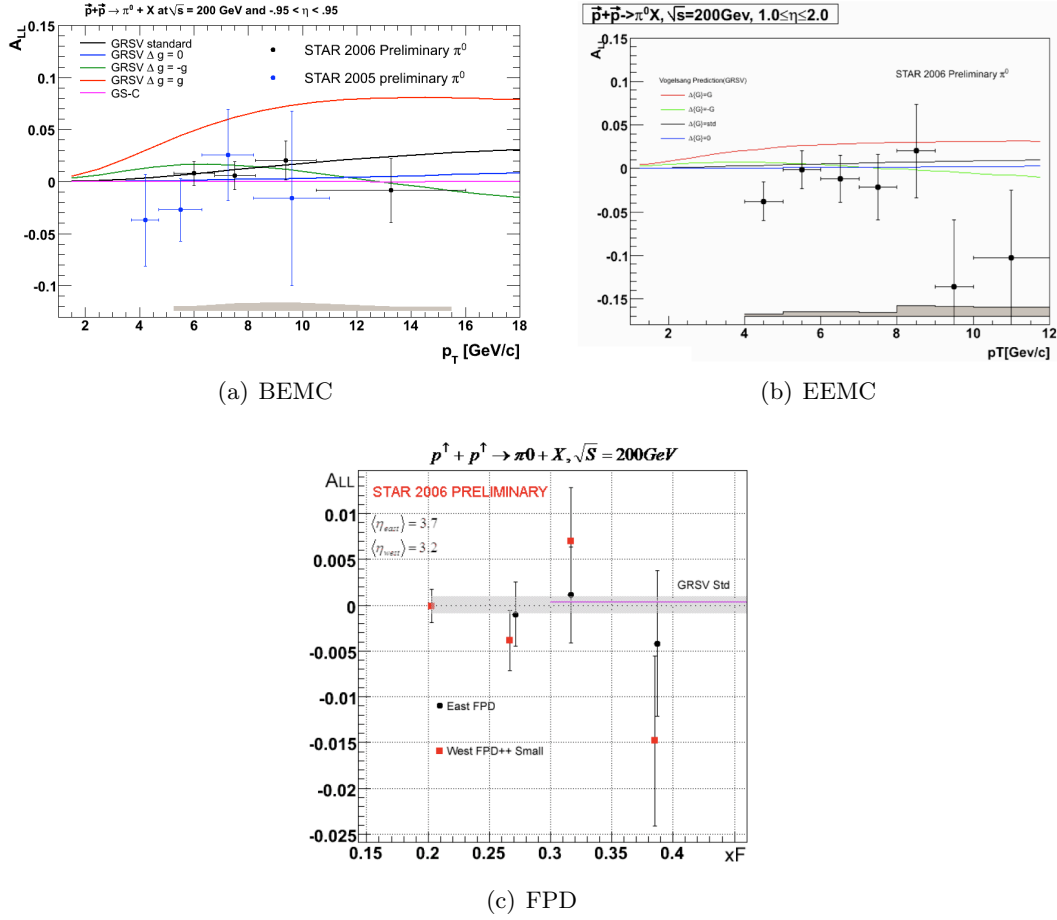
Figure 2. Asymmetries of inclusive neutral pion production extend over a wide range in rapidity at STAR and have a rather different systematic uncertainty profile than the inclusive jet A_{LL}, making them an excellent complementary set of measurements.

region. The FPD modules can be positioned at different transverse distances from the beamline, allowing for measurements at multiple values of η.

Figure 2 displays A_{LL} results for each of these calorimeters [11, 12]. As in the case of the inclusive jet measurement, the data are compared to predictions assuming various input distributions for the polarized gluon distribution. In contrast to the jet measurement, the bias from the triggering system in π^0 analyses is typically negligible. A thorough understanding of π^0 reconstruction is also an important prerequisite for future direct photon measurements.

4. Charged Pions

Figure 3 presents STAR's preliminary results for charged pion A_{LL} opposite a trigger jet, plotted versus $z \equiv p_T(\pi)/p_T(jet)$ [13]. Point-to-point systematic uncertainties from a variety of sources are summed in quadrature and included as the gray bars. The dominant systematic uncertainty arises from the use of the JP trigger to select events. This trigger a) hardens the jet p_T spectrum in each z bin, and b) preferentially selects quark jets over gluon jets. The first effect is quantified by using Monte Carlo to determine the trigger efficiency for jets at a given p_T, and the theoretical predictions for A_{LL} for this observable are adjusted to account for that efficiency [14]. Future analyses with greater statistical precision may be able to avoid this requirement by binning in
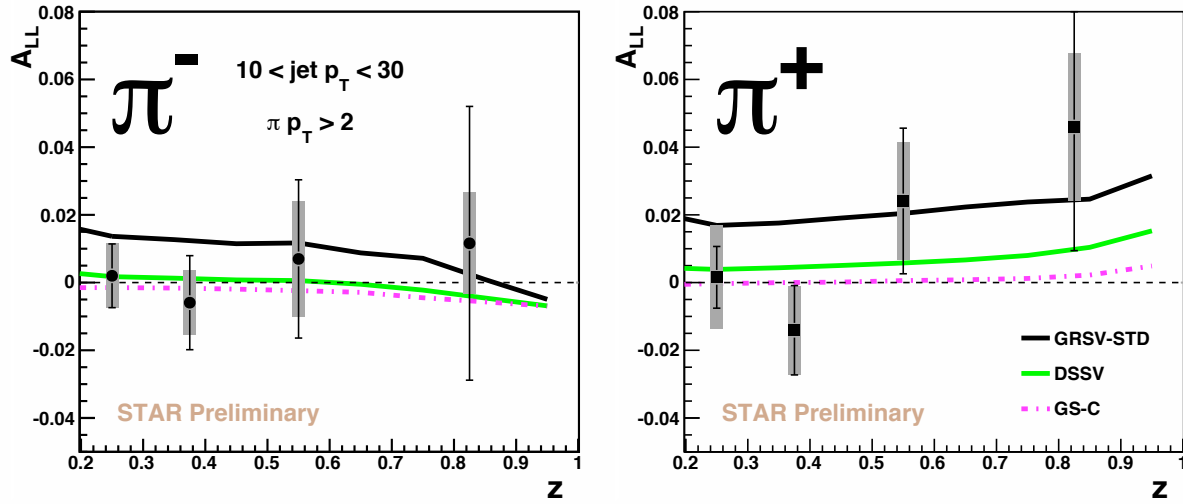
Figure 3. STAR's TPC allows for efficient reconstruction of charged pions over a wide range in transverse momentum, but the lack of a dedicated triggering system for charged pions makes an unbiased inclusive A_{LL} a challenge. The asymmetries shown here are obtained by triggering on a jet and counting pions on the opposite side of the event.

both jet p_T and z. For b) STAR investigates how our LO Monte Carlo evaluation of A_{LL} changes when we require the JP trigger condition. Specifically, we compare our MC asymmetries for the JP trigger with MC asymmetries that incorporate only the trigger *efficiency*, not the subprocess bias. The difference between the two is a measure of how the trigger's preference for quark jets affects A_{LL}.

5. Conclusions and Outlook

STAR has a robust program of inclusive double-spin asymmetry measurements. Global analyses incorporating STAR data have established significant new constraints on the polarized gluon distribution in the proton. These measurements set the stage for a program of correlation measurements at both $\sqrt{s} = 200$ GeV and 500 Gev that will extend the sampled x range and more precisely map out the x-dependence of the polarized gluon distribution.

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